APPLICATION OF VETIVER SYSTEM TECHNOLOGY FOR RIVERBANK AND COASTAL DIKE STABILISATION IN VIETNAM

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Presented at the Southern African Association of Geomorphology (SAAG) 2017 Conference, 25-28 July 2017, Swaziland

SLOPE STABILITY

Slope stability is based on the driving forces which promote down slope movement of material, while resisting forces deter movement. When driving forces overcome resisting forces, these slopes become unstable.

In upland slope the main driving force is gravity, for stream banks and coastal zone, in addition to gravity, other factors such as wetness, flow velocity and wave action have a major effect on its stability. *The main resisting force for stream banks and coastal zone is the material's shear strength and wetness.*

Water plays a key role in slope failure in riverbank and coastal dikes:

- It erodes the base of slopes, removing support.
- Water increases the driving force by filling previously empty pore spaces and fractures
- The presence of water results in *pore water pressure that reduces the shear strength* of the slope material.

Vetiver Characteristics - Roots

For more information on Vetiver unique attributes, please refer to Slope Stability with Vetiver System Technology presentation at this Conference

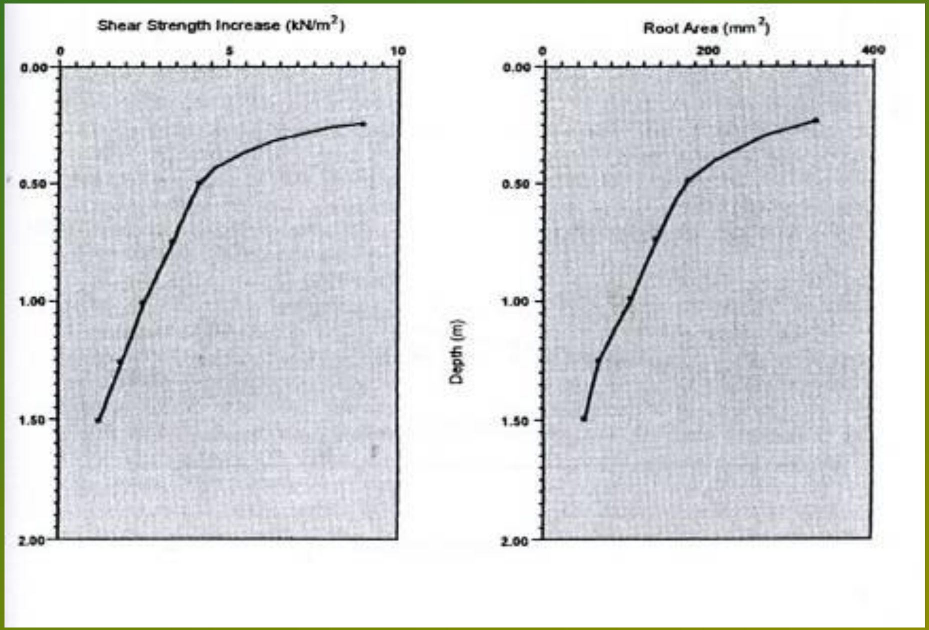
Very fine and massive root system

One year old with 3.3m deep root system

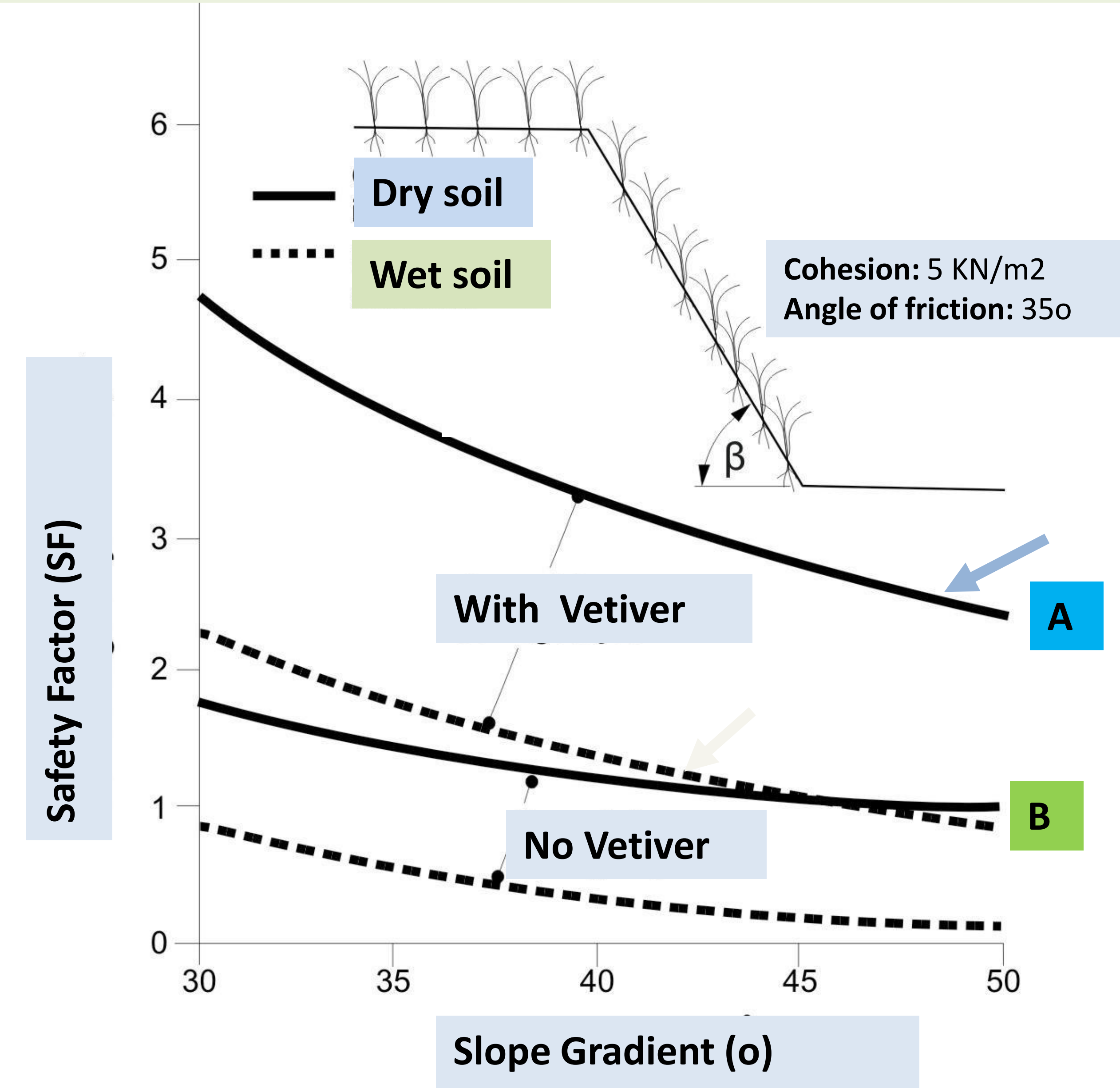
Vetiver Characteristics - Roots

STRONG, DENSE, DEEP & PENTRATING ROOTS

- **Tensile strength 1/6th of mild steel = 75Mpa**
- **Improve soil sheer strength by 45%**
- **Interlocking root matrix create vast, dense and strong underground walls, reinforcing soil conditions**
- **Fine root structure – does not interfere with the integrity of infrastructure**



EFFECT Of VETIVER ON SLOPE STABILITY ON DRY AND WET SOIL



On dry soil with Vetiver (A), when slope gradient increases from 30o to 50o, FS reduces from 4.8 to 2.5

When dry soil with Vetiver (B) became wet, FS reduces from 4.8 to 2.2 at 30o slope

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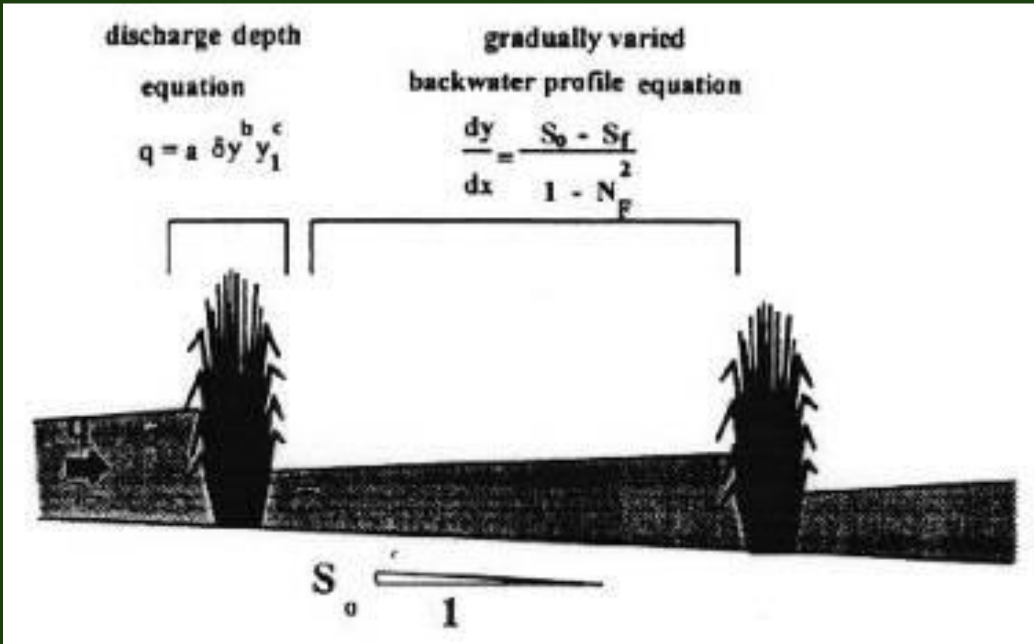
VETIVER RESEARCH AT UNIVERSITY OF SOUTHERN QUEENSLAND, AUSTRALIA

Hydraulic Flume: Two concrete testing channels, 2m wide and 20m long

SPECIFIC FINDINGS OF VETIVER RESEARCH IN AUSTRALIA

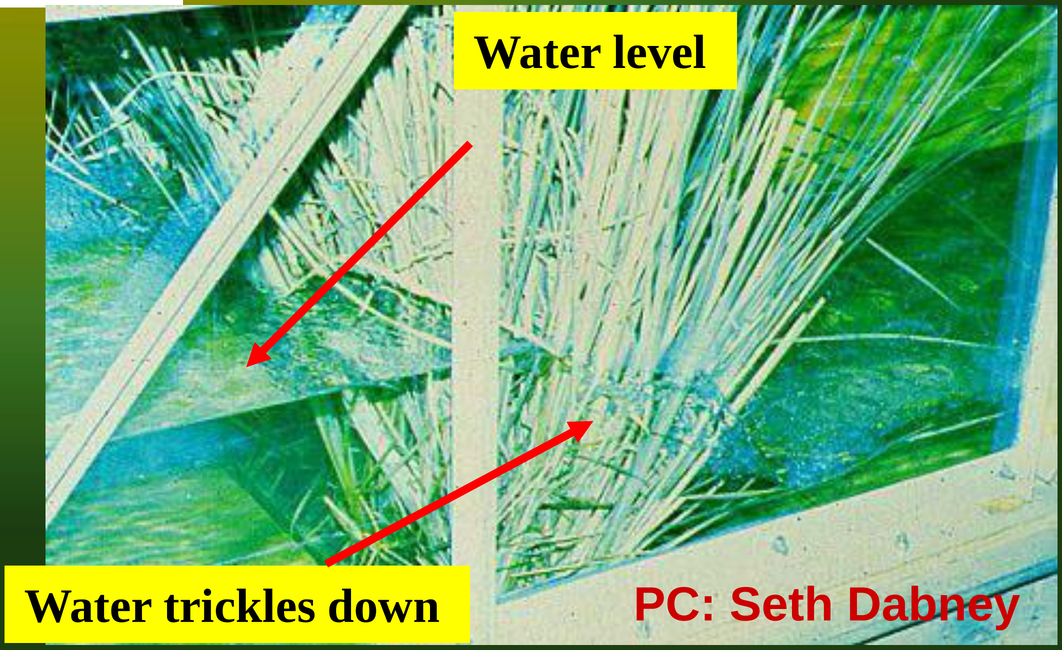
- **Dense plantings of vetiver grass in deep, un-submerging flows had a high hydraulic resistance**
- **Hedges were found to be in hydraulic retardance class A, with resistance decreasing with increased hedge spacing**
- **The cross pattern planting had hydraulic retardence class B**
- **The Manning "*n*" was found not to quantify retardence adequately.**
- **Rows of vetiver are more suited to steep slopes/highly erosive flows where sedimentation is unlikely or acceptable**

Hydraulic Characteristics

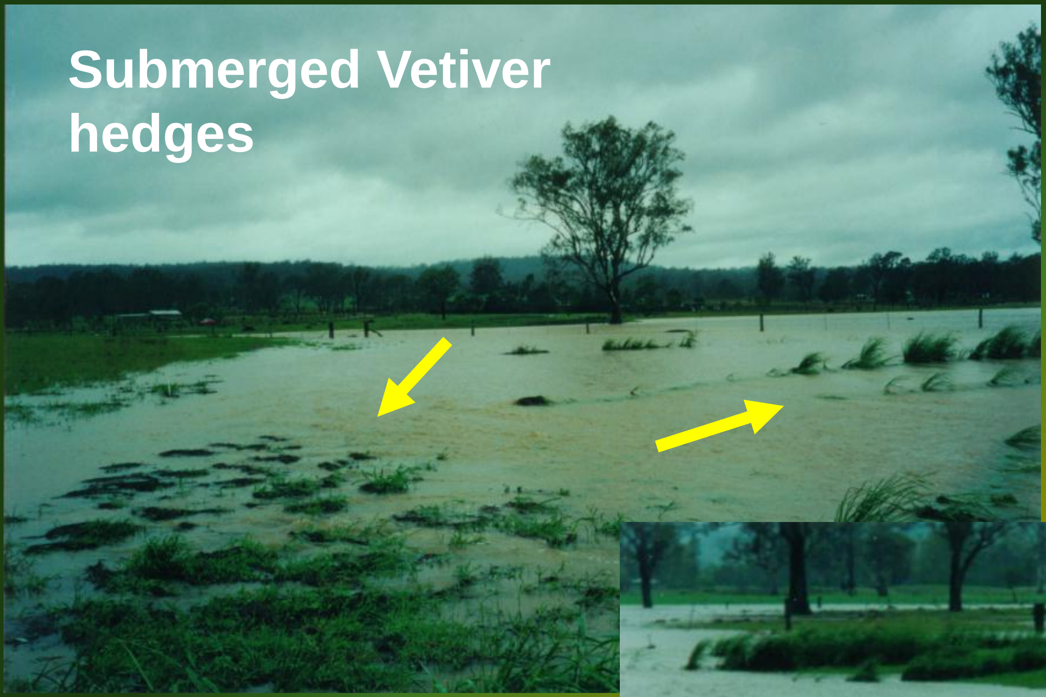


Under shallow or low velocity flow, Vetiver act as a barrier that reduces flow velocity and traps eroded sediment. It can maintain its erect stance in a flow as deep as 0.6-0.8m

Withstand flow velocity higher than 3.5m/sec in river under flood conditions and up to 5m/sec in a flooded drainage channel.

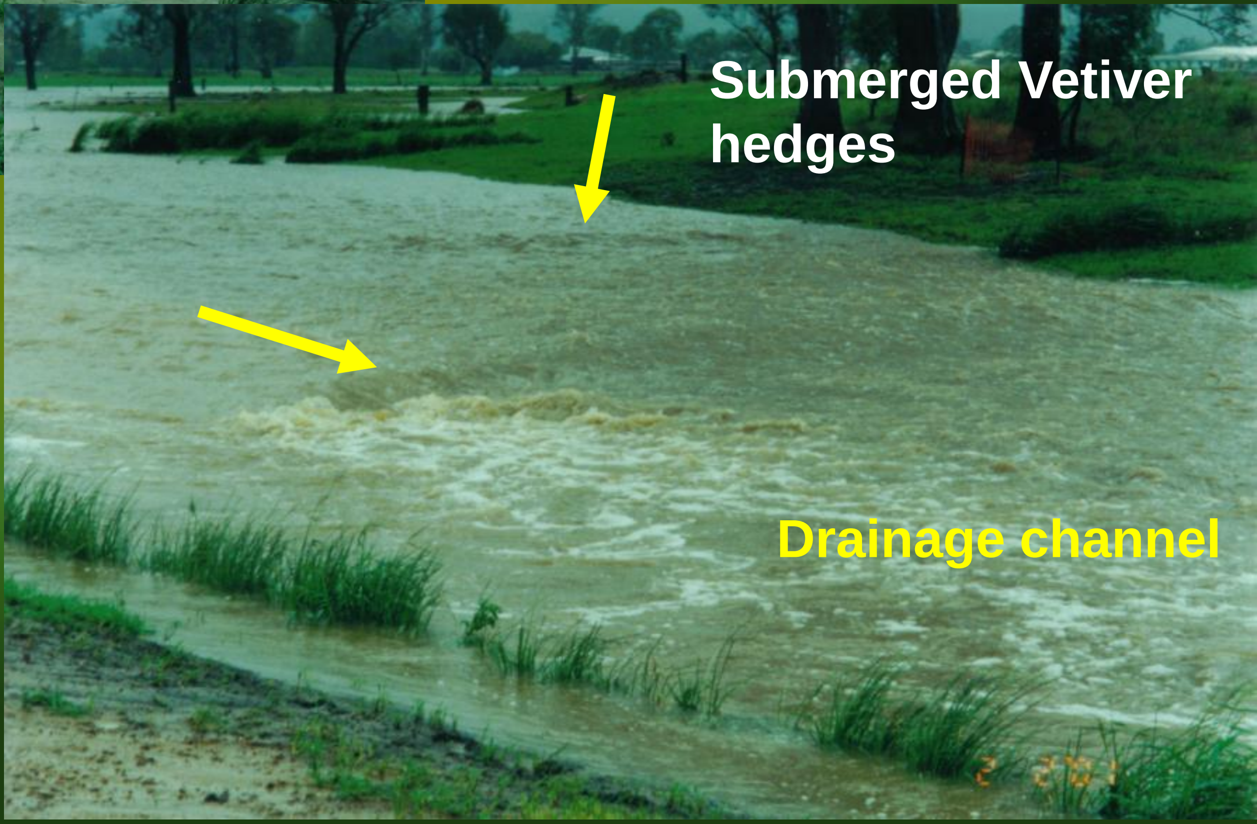


CHANNEL FLOW RESEARCH IN AUSTRALIA



Hydrologic data of a drainage channel was monitored to determine its flow velocity

A big storm hit the area 3 months after planting and the whole site was under water



Flow velocity of *5m/second* was recorded during the peak flooding period

Despite its young age (3 months), minimal damage to vetiver occurred

VETIVER RESEARCH AT DELFT TECHNICAL UNIVERSITY, HOLLAND

GERRIT JAN SCHIERECK Coastal Engineer

Irene Maaskant (2005): *Potential Application of Vetiver and Cyperus rotundus on dikes*. Master of Engineering Thesis

- ***Cyperus rotundus*** **is commonly used to protect dikes from wave erosion by boats or wind. But it only thrives in fresh water and therefore it is not suitable on dykes near salty or brackish water.**

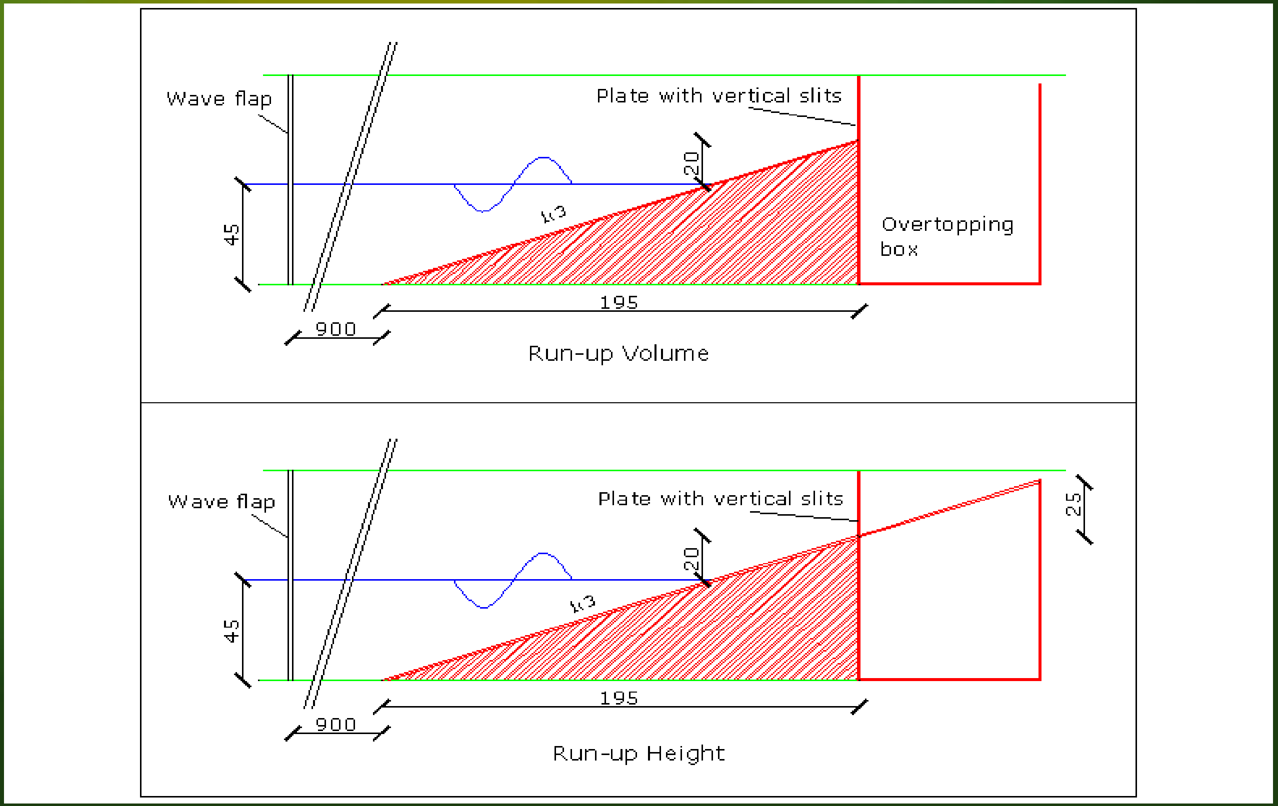
- ***Cyperus rotundus*** **grows very slowly, taking 17 weeks to cover the soil surface with wide space new stems. When Cyperus is exposed to waves at that time, the soil can easily be flushed away.**

- **Although Vetiver cannot grow in full seawater, it has 60% of optimal growth in brackish water (9 ‰). Vetiver can be applied on dikes in fresh and brackish water.**

- **Vetiver is very fast growing with deep fine root system, protecting soil surface from wave erosion by boats or wind**

Auke Algera (2006): *Run-up reduction through Vetiver grass.* Master of Engineering Thesis

A single hedge of Vetiver grass planted on the outer slope of a dike can reduce the wave run-up volume by 55%, in contrast with sod-forming grasses that give no reduction. Planting multiple hedges along the contour of the outerslope might result in even more reduction. The application of Vetiver grass on existing dikes may provide a substantial reinforcement of these dikes.

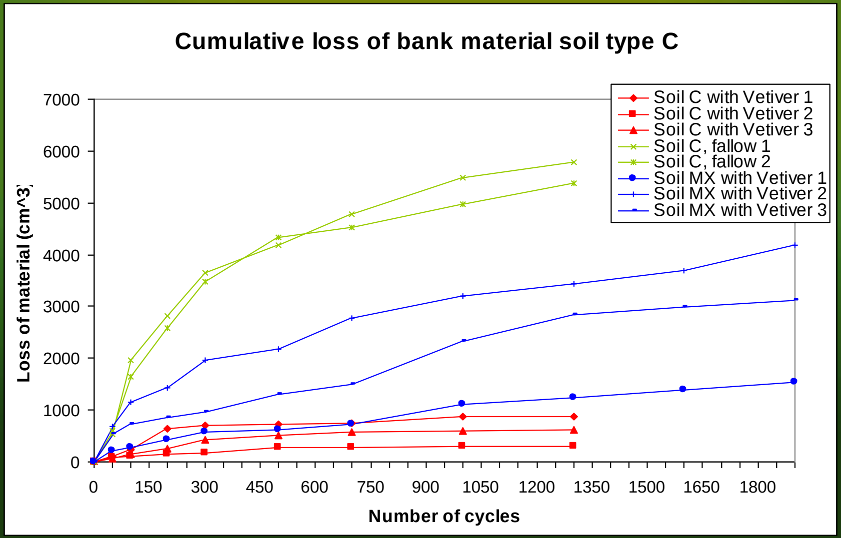


Jaspers Focks (2006): *Vetiver grass as bank protection against vessel-induced load.* Master of Engineering Thesis

Laboratory tests showed an increase in the factor of safety of approximately 20% by the presence of Vetiver grass due mainly to an increase in undrained shear strength.

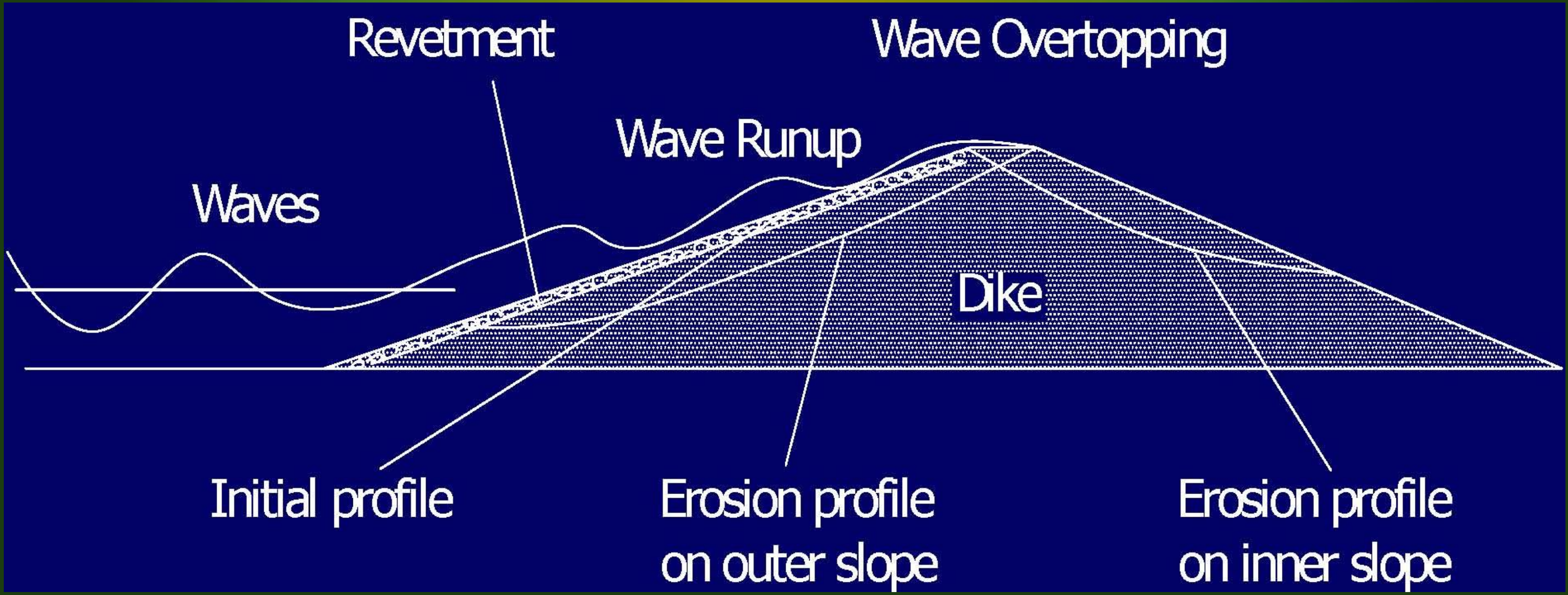
The drawdown caused by passing ships was reproduced with the use of a wave flume.

- The amount of eroded material of cohesive soil (clay) was approximately 8-10 times smaller using Vetiver grass.
- The erosion of non-cohesive soil was also reduced drastically.
- A combination of cohesive soil and Vetiver grass did have the lowest amount of erosion, and after approximately 800-1000 cycles.

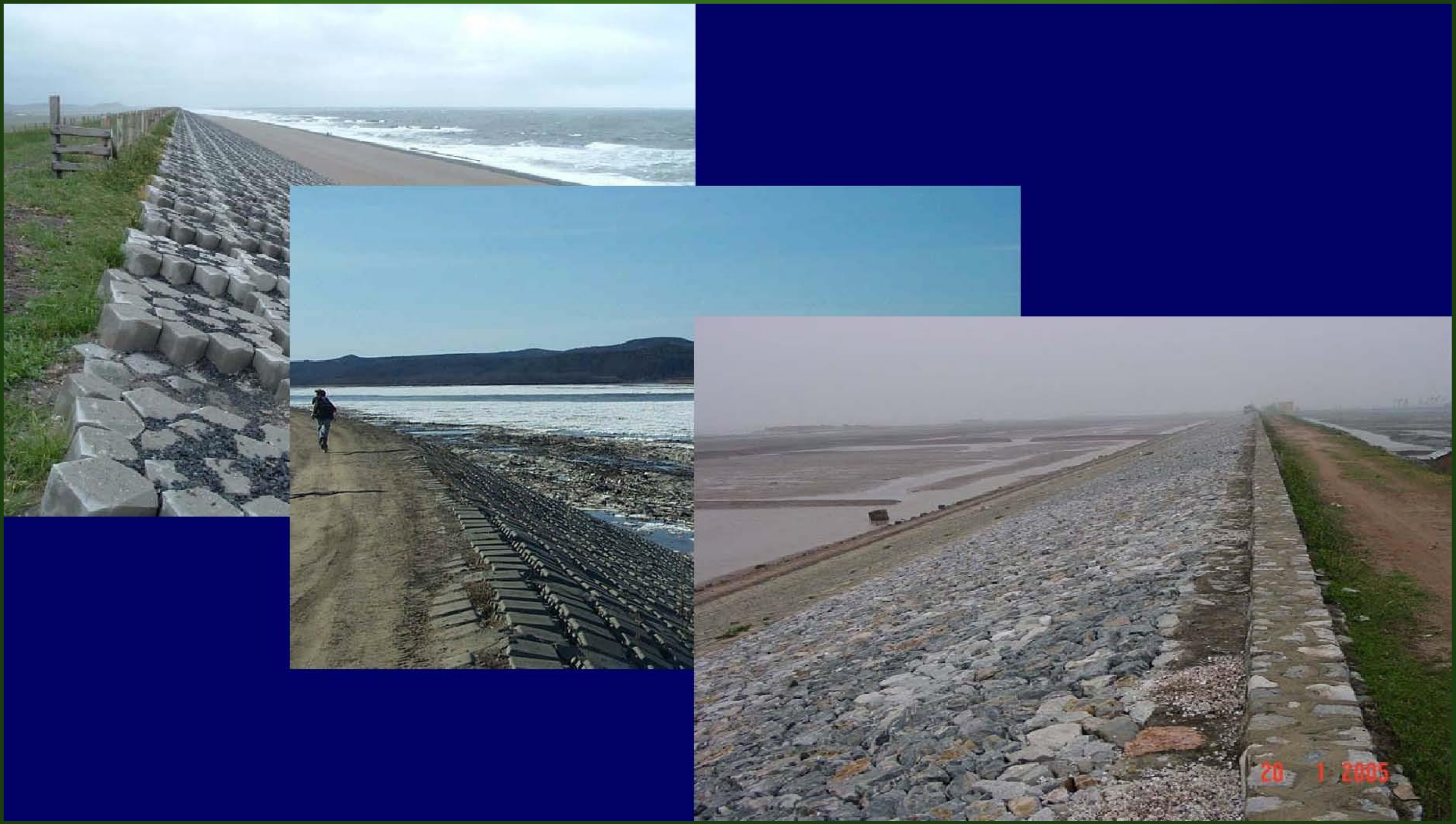


Vu Minh Anh (2007). ***Reduction of wave over-topping (run-up) by vetiver grass. Master of Engineering Thesis*****.**

The reduction of wave overtopping of more than 60% was measured when Vetiver is planted in front of the slope. Applying these results to a sea dike in Vietnam resulting in a reduction of 0.5m of the crest height, which corresponds to a reduction of 12.6% of the costs in case of two Vetiver hedges are planted on the outer slope.



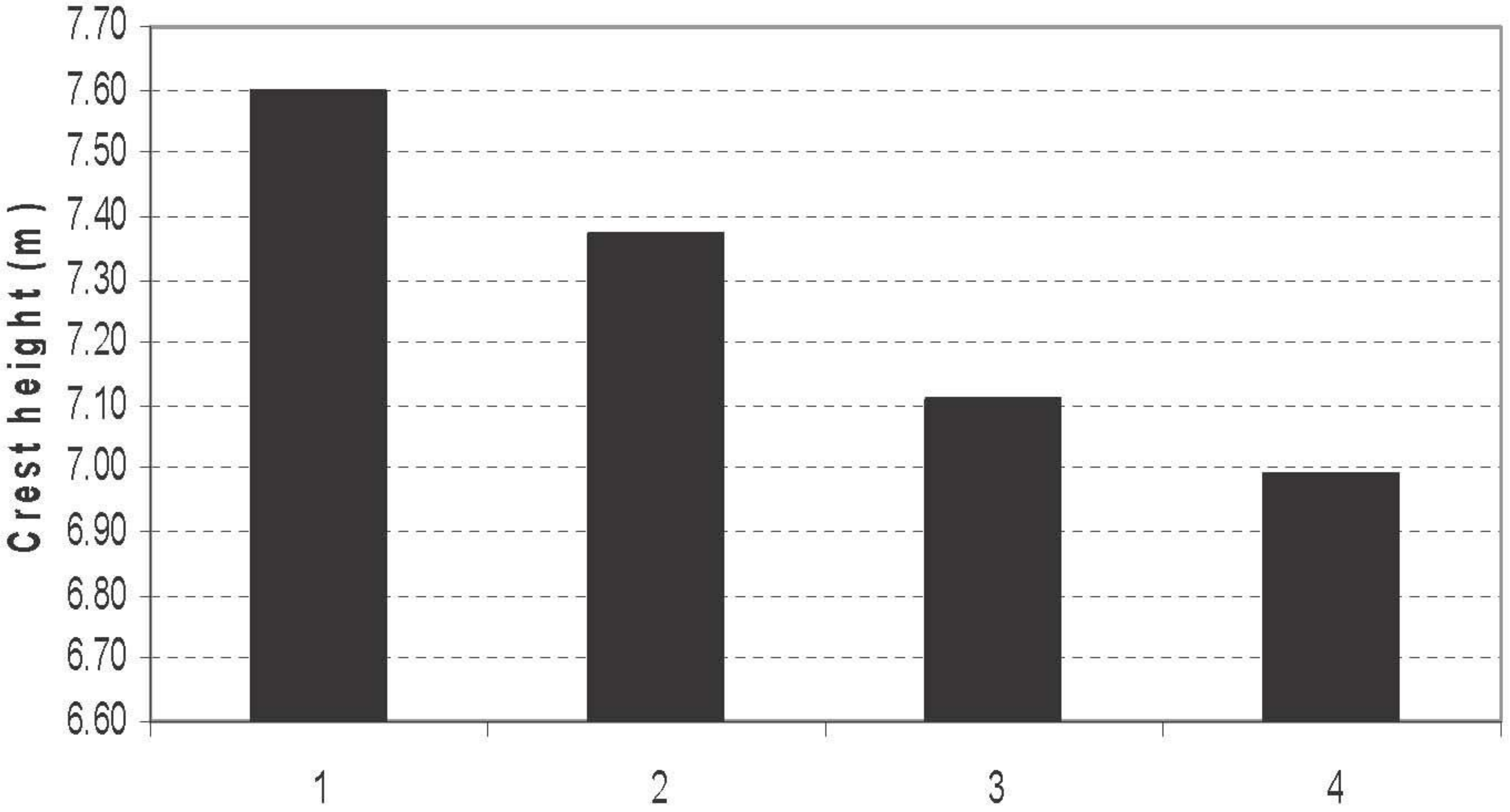
Sea dike in Vietnam protected by very costly conventional hard structure



Storm surges and sea dike wall protected by Vetiver

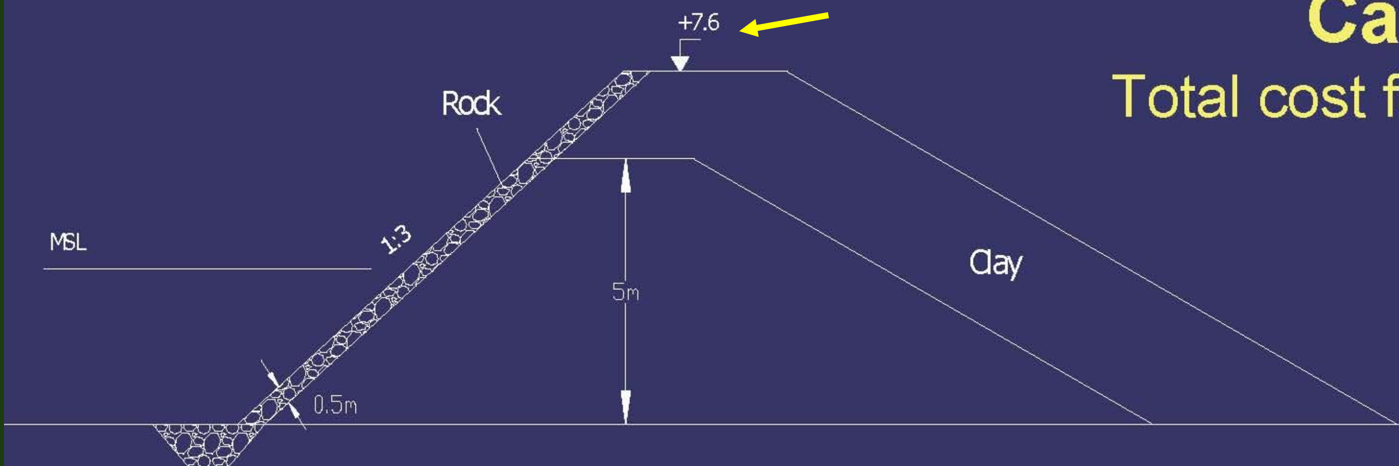
Case Study

Crest height of sea dike



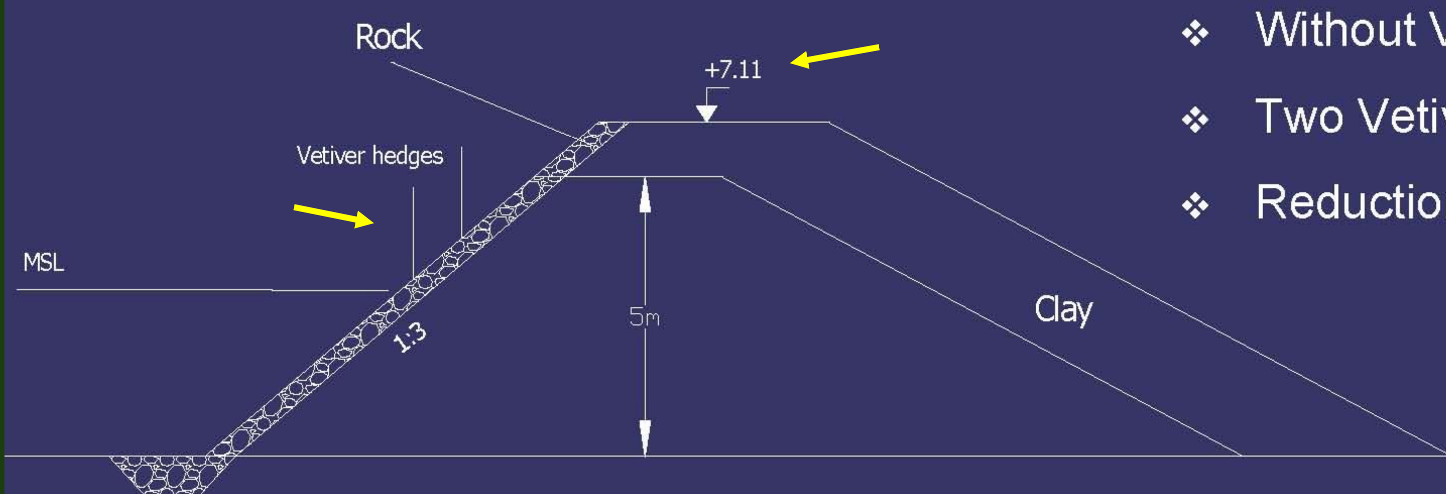
No Hedge One Hedge Two Hedges Three Hedges

When 2 rows of Vetiver planted on sea dike rock wall to reduce storm surges, crest height was reduced from 7.6m to 7.11m, resulting in construction cost saving of 12.6%



Case Study

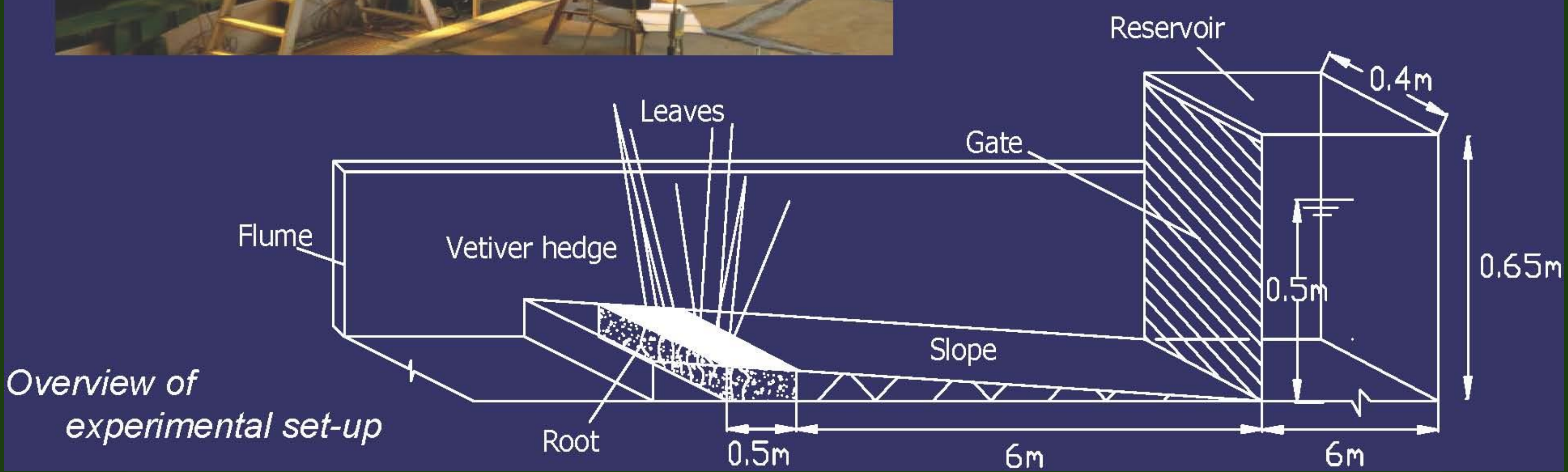
Total cost for one meter length



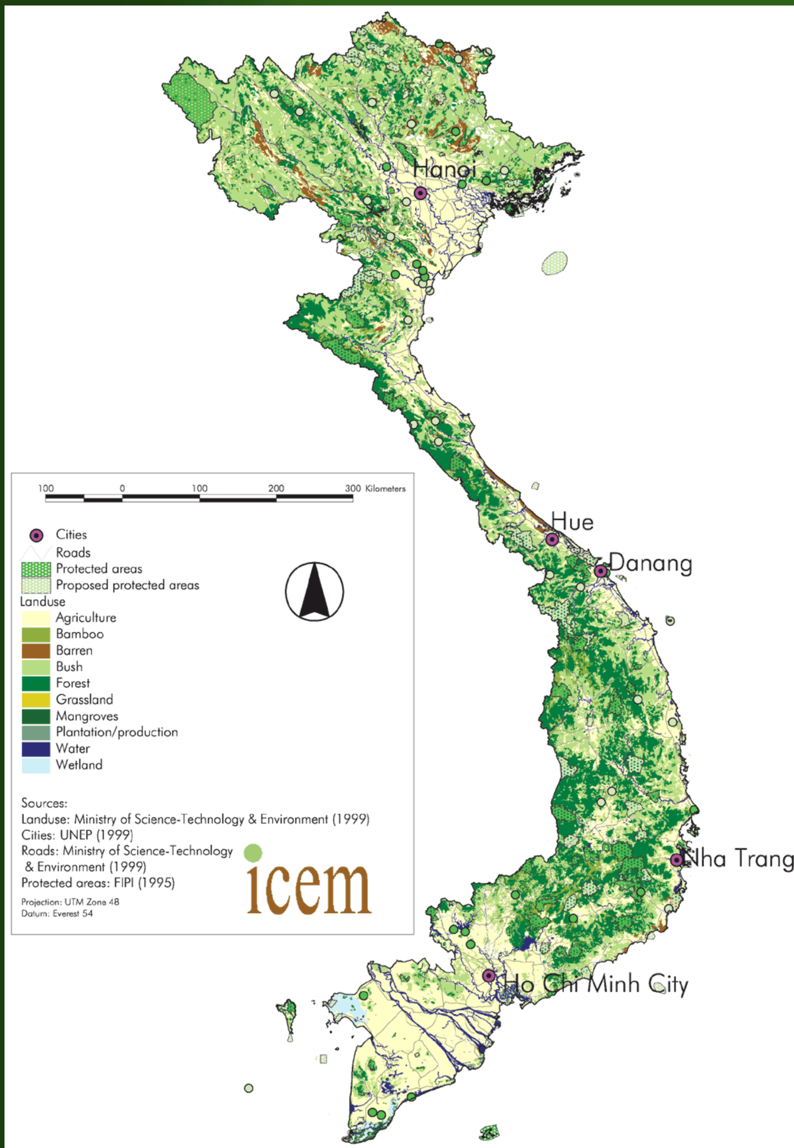
- Without Vetiver grass: $147,5
- Two Vetiver hedges: $128,96
- Reduction 12,6% total costs

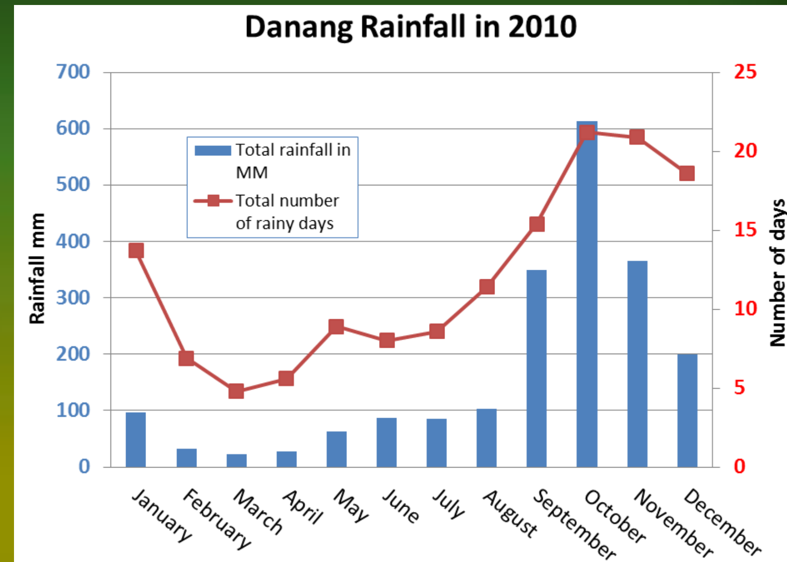
Laboratory set up and model

Model set-up



RIVER AND CANAL BANK STABILISATION IN THE CENTRAL PROVINCES AND ITS CLIMATE CONDITION





Typhoon Ketsana, 1999
$340 million lost
Thousands of deaths

RIVERBANK EROSION IN THE CENTRAL PROVINCES

RIVERBANK STABILISATION IN QUANG NGAI

RIVERBANK STABILISATION IN QUANG NGAI

Fresh water

RIVERBANK STABILISATION IN QUANG NGAI

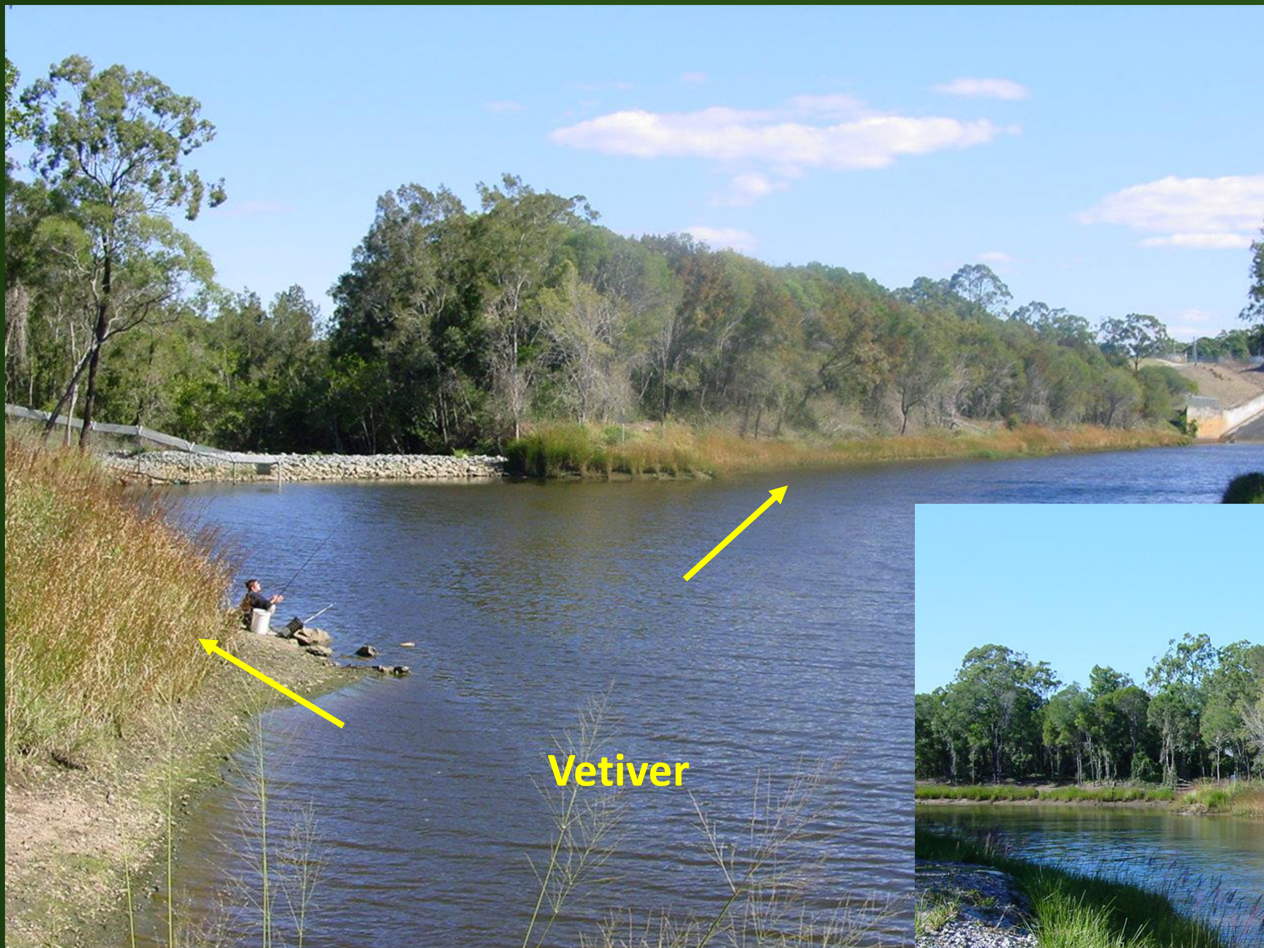
Brackish water

CANAL BANK STABILISATION IN QUANG NGAI

CANAL BANK STABILISATION TRIALSIN QUANG NGAI

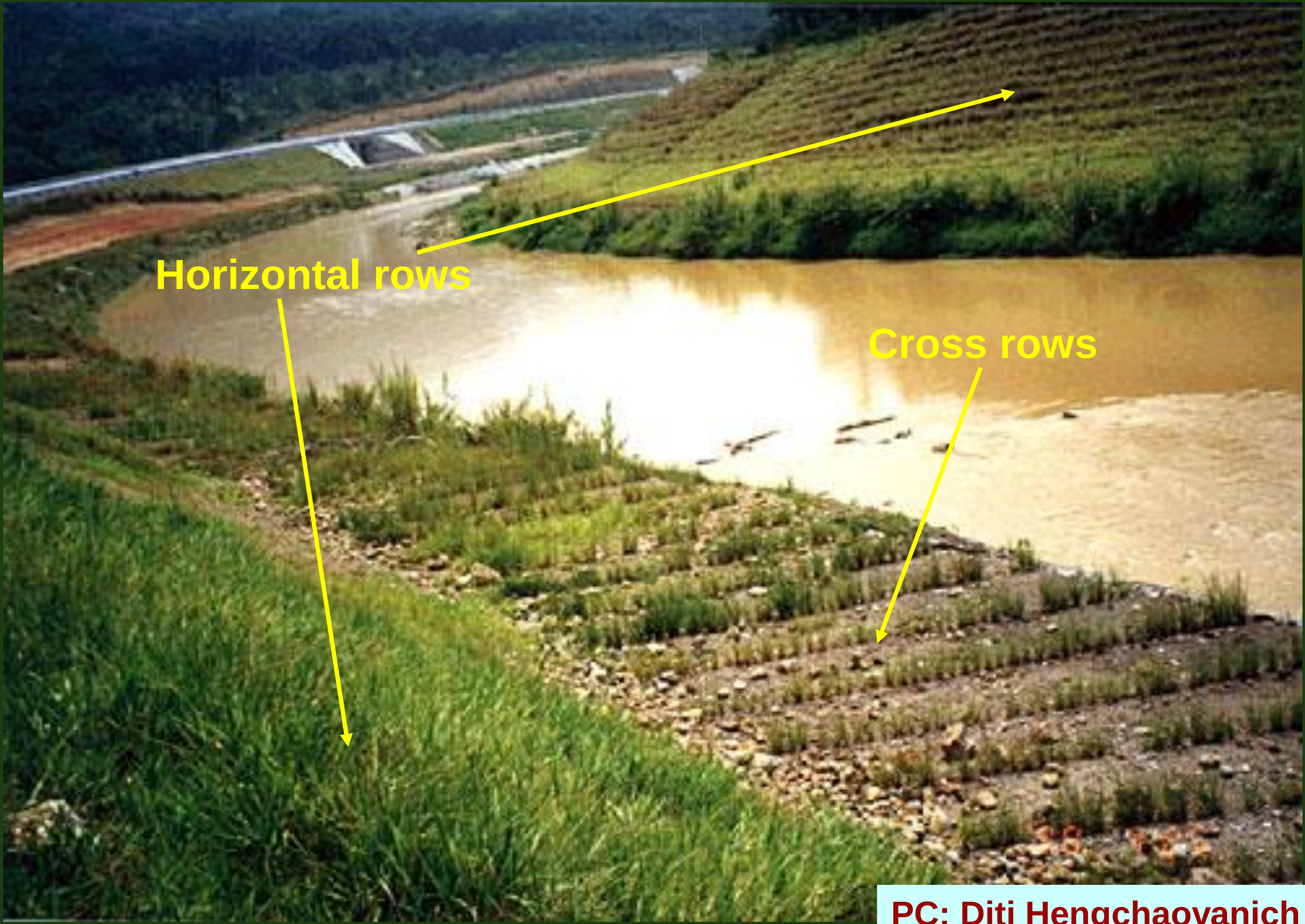
VERY SUCCESSFUL RIVERBANK STABILISATION

GLOBAL CASE STUDIES OF SUCCESSFUL APPLICATIONS IN RIVER AND CANAL BANKS, SEA AND ESTUARY DIKES



AUSTRALIA

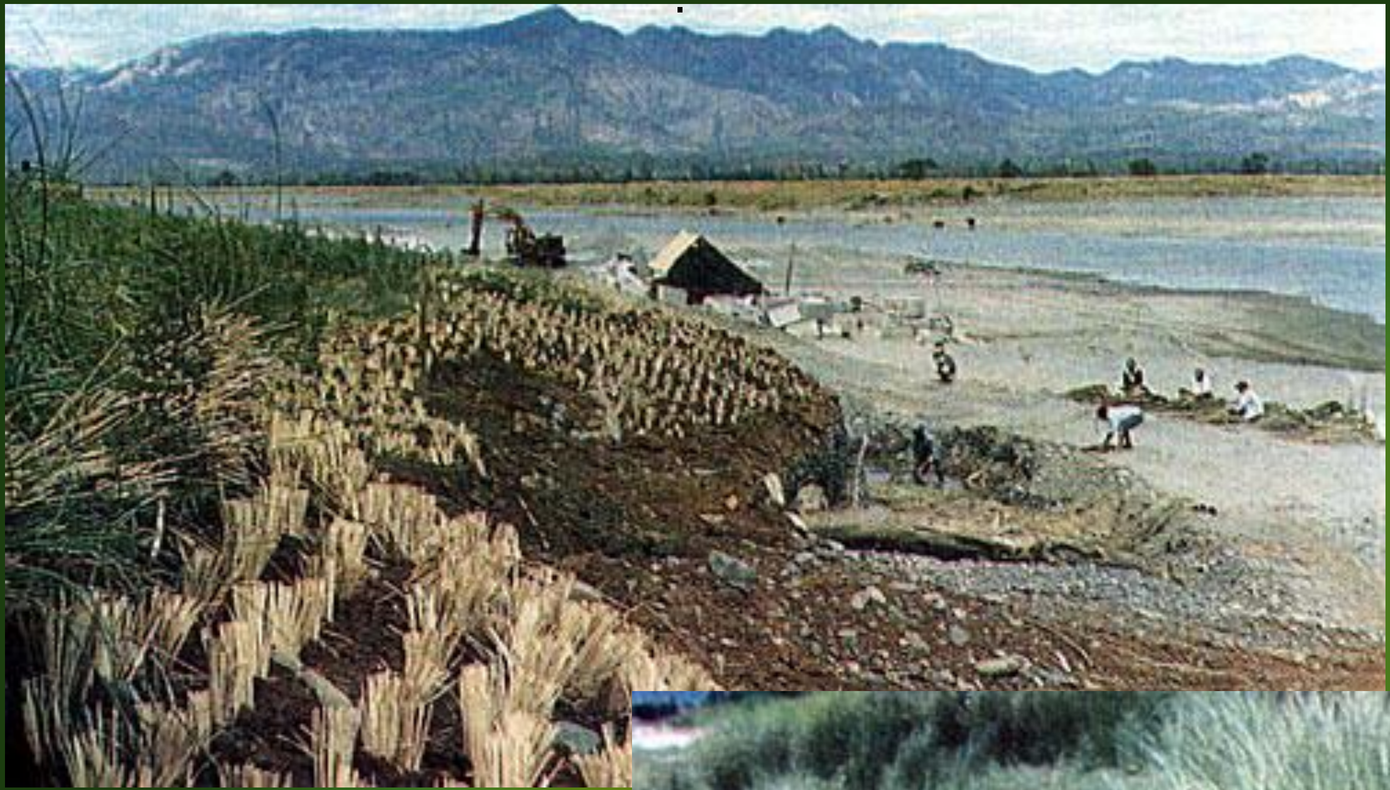
MALAYSIA



PC: Diti Hengchaovanich

THAILAND

PHILIPPINES



Estuary with frequent inundation by brackish water

VIETNAM

Mekong Delta riverbanks

Estuary dikes

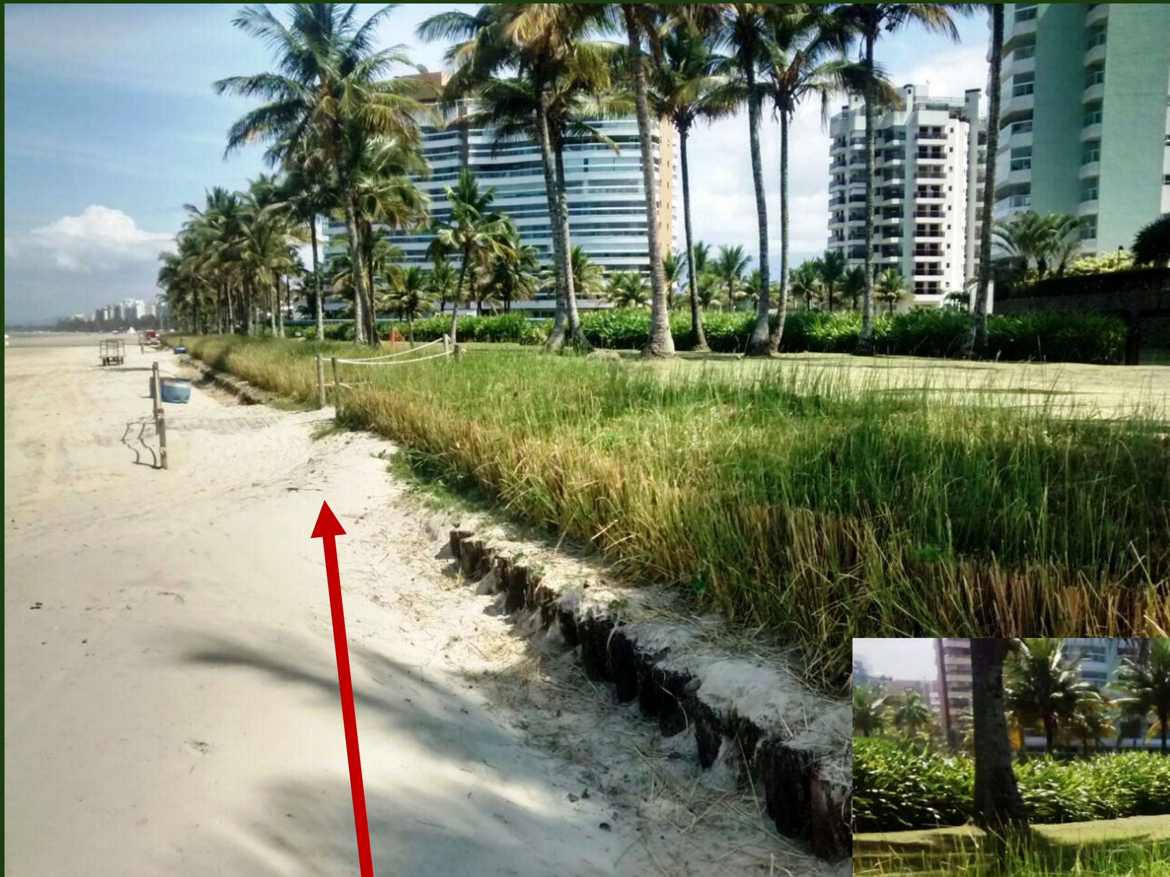
BRAZIL

COAST DUNE PROTECTION IN SAO PAOLO

PC: Paula Leão Pereira

BEACH EROSION

Vetiver planting to protect sandy beaches erosion caused by tidal wave erosion and storm surges



Storm surges inundated vetiver planting several times every year, but it fully recovered within a few weeks

Vetiver stop sand drift caused by storm surges

Vetiver planting protects these upmarket beach front villas from tidal wave erosion, storm surges and sand blast